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Fisheries and Watershed Assessment

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1. PRESENT CONDITIONS IN STREAMS COVERED BY THE PLAN

1.1. STUDY SITES

PL's ownership contains seven major river drainages including Yager and Freshwater creeks, and the Bear, Elk, Eel, Van Duzen, and Mattole rivers. To facilitate the analysis of this extensive property, PL divided its ownership into five watershed assessment areas or WAAs (Humboldt Bay, Yager, Van Duzen, Eel, and Bear-Mattole). These WAAs were delineated, in part, using the boundaries of the state of California's Planning Watersheds and include non-PL or "off-ownership" lands to ensure that all areas within the relevant planning watersheds were considered. A description of the location, physical characteristics, major watercourses and dominant vegetation within each WAA is given below.

1.1.1. Humboldt Bay WAA

The Humboldt Bay WAA is located in the northwestern portion of PL's ownership and is situated approximately 5 miles south of Arcata, California (Figure 1). The WAA is 127,682 acres in size, of which 36,740 acres are located on PL's ownership. Elevations within the WAA vary from sea level to 2,800 ft. It is defined by the geographic watershed boundaries of Jacoby Creek to the north, Freshwater Creek and Elk River to the east, Salmon Creek to the south, and Humboldt Bay to the west. The Humboldt Bay WAA is dominated by two primary drainages, Freshwater Creek and the Elk River, both of which generally flow in an east-west direction. The portion of the Humboldt Bay WAA within PL's ownership is comprised primarily of late seral forest. PL's ownership includes the upper portion of the South Fork Elk River colloquially known as the "Headwaters Forest." PL has agreed to sell this portion of the ownership to government entities for the purpose of creating an old growth reserve.

1.1.2. Yager WAA

The Yager WAA is located in the north-central portion of PL's ownership and is situated approximately 8 miles northwest of Scotia, California (Figure 1). The WAA is 84,554 acres in size, of which 33,746 acres are located on PL's ownership. Elevations within the WAA vary from 400 to 2,800 ft. The WAA is defined by the geographic boundaries of the Yager Creek watershed from its headwaters to a point approximately 3 miles above its confluence with the Van Duzen River. The Yager WAA is dominated by two primary drainages, the generally east-west flowing Yager Creek, and the north-south running Lawrence Creek. Yager Creek divides to the east into three forks, the North Fork (NF), Middle Fork (MF), and South Fork (SF). The portion of the Yager WAA within PL's ownership is composed primarily of open and young forest with some late seral and mid-successional forest. Oak-grassland communities are present in much of the headwaters area of this WAA.

1.1.3. Van Duzen WAA

The Van Duzen WAA is located in the central portion of PL's ownership and is situated approximately 4 miles northeast of Scotia, California (Figure 1). The Van Duzen WAA is defined by the geographic boundaries of the Van Duzen River watershed from a point approximately 3 miles above the confluence with the Eel River and extending eastward about 22 miles. The WAA is 55,341 acres in size, of which 24,876 acres are located on PL's ownership. Elevations within the WAA range from 40 to 1,000 ft. The primary drainage within the Van Duzen WAA is the east-west flowing Van Duzen River. The portion of the Van Duzen WAA located within PL's ownership is comprised primarily of mid-successional forest dominated by redwood and Douglas fir.

1.1.4. Eel WAA

The Eel WAA comprises most of the eastern portion of PL's ownership. This is the largest WAA at 427,337 acres, of which 73,314 acres are within PL's ownership (Figure 1). The WAA is defined by the Eel River drainage but excludes the headwaters area and the Van Duzen River drainage. Elevations within the WAA range from sea level to approximately 5,000 ft. The Eel WAA is dominated by the Eel River which divides into the North Fork, Middle Fork and South Fork Eel rivers. Most of PL’s ownership in the WAA borders the mainstem Eel River below its junction with the South Fork. The portion of the Eel WAA within PL's ownership is comprised primarily of late seral forest with some open, young, and mid-successional forest.

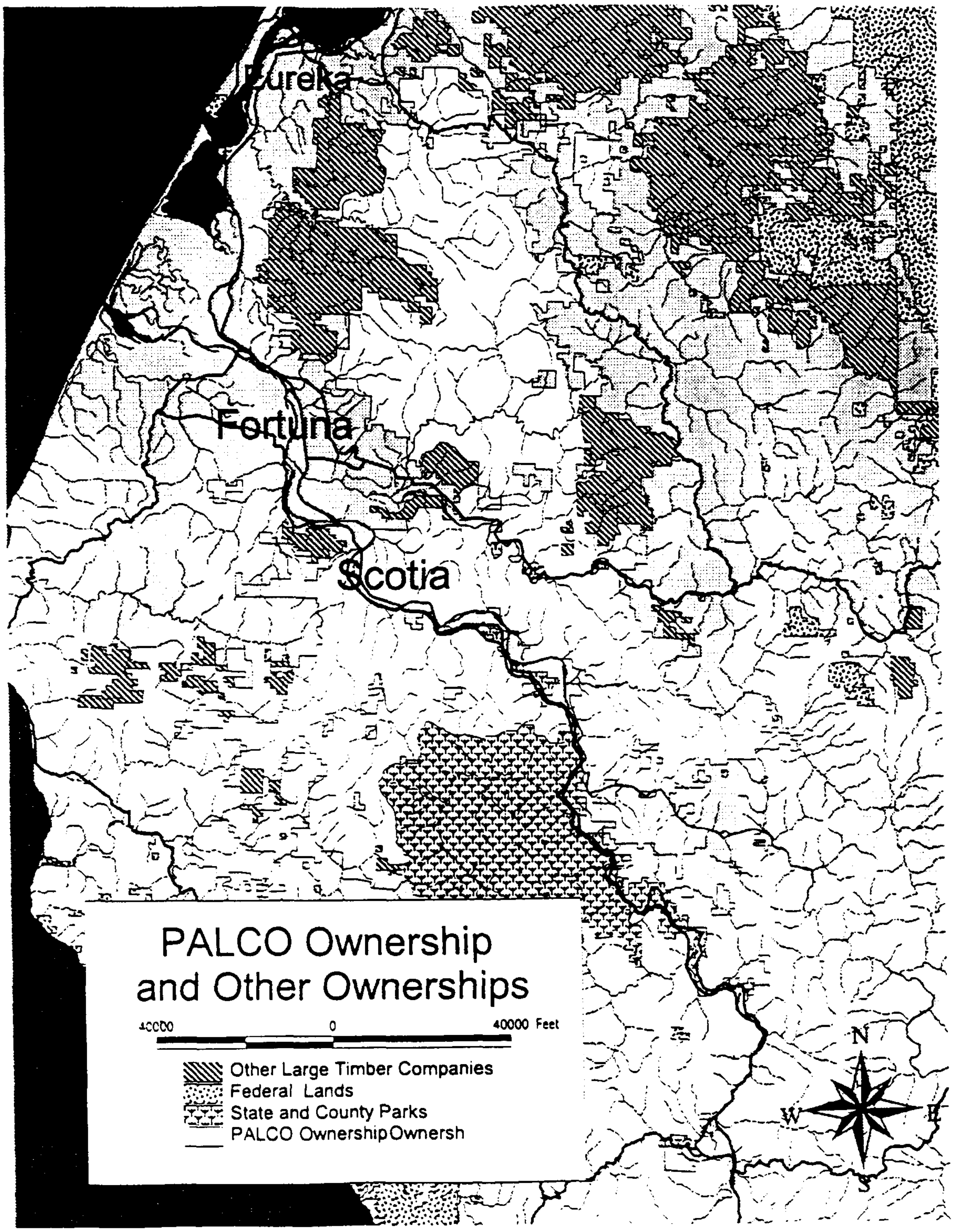
1.1.5. Bear-Mattole WAA

The Bear-Mattole WAA is located in the southern portion of PL's ownership and is situated southwest of Scotia, California (Figure 1). The Bear-Mattole WAA is defined by the geographic watershed boundary of the Bear River to the north and east and the mainstem Mattole River and its northern tributaries to the south and east. The WAA contains 144,464 acres, of which 29,753 acres are within PL's ownership. Elevations within the WAA range from sea level at the mouth of the rivers to 2,500 ft in the headwater areas. The Bear-Mattole WAA is dominated by two primary drainages, the Bear and the Mattole rivers. The portion of the Bear-Mattole WAA located within PL's ownership is comprised primarily of hardwood forest with some late seral forest. Much of the non-ownership land within the WAA contains oak-grassland and Douglas fir forest.

1.1.6. WAA6

The watershed assessment area named WAA6 is composed of all the pieces of PLs ownership that do not fall within one of the five named WAAs. Presently, this consists of 3,586 acres which are located just east of the northern ownership in the Humboldt Bay WAA. The parcels are in the Butler Valley and the Iaqua Buttes hydrologic units. In the future, any new land acquired that does not fall within one of the five established WAAs will also be added to WAA6. Because this land constitutes such a small portion of the ownership and because they represent such a small portion of the hydrologic units in which they are located, existing conditions are not

-Figure 1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detailed here. However, all HCP measures in this document will apply to these lands just as they do to the rest of PLs ownership.

1.2. DATA SOURCES AND METHODS USED TO ASSESS CURRENT CONDITIONS

Existing data were used to evaluate stream conditions and fish distribution and abundance. A substantial portion of the existing data was collected by state agencies (particularly California Department of Fish and Game [CDF&G]). However, PL has also collected considerable data as part of its ongoing stream monitoring program. Data sources included:

- **Monitoring data collected by PL and CDF&G.** Both CDF&G and PL have conducted monitoring studies within streams on PL's ownership. Monitoring data were collected from specific sites, or points along streams including 46 fine sediment (i.e., sediments <0.85 mm in diameter) sampling sites, 28 temperature sampling sites, and 69 macroinvertebrate sampling sites. Thalweg mapping data were also available for a few sites. CDF&G data on temperature and fine sediments were available for selected dates and times from 1991 to 1994. PL's monitoring data for invertebrates, fine sediments and temperature were available from 1994 to 1996. Additional discussion of the availability and importance of monitoring data are presented in Volume II Part F, Volume IV Part D, and in R2 (1996a).

- **CDF&G datasets on fish populations.** Fisheries data were also collected from selected streams on PL's ownership from 1989 to 1995 through a program developed by the Inland Fisheries Division of CDF&G. Data were available for 53 streams on PL's ownership, and collectively provided information on redds (trout and salmon spawning nests), fish carcasses, and juvenile distribution.

- **CDF&G's Stream Habitat Database.** Stream habitat data were obtained from CDF&G's GIS database. These data were collected as part of a systematic inventory of streams along the North Coast designed to identify possible fisheries restoration projects. Data were collected from 1989 to 1996, but most data were obtained in 1992 or subsequent years. This database contains information for over 120 stream segments on PL's ownership and represents the most comprehensive dataset on stream conditions available for the North Coast.

- **CDF&G's Large Woody Debris Database.** From 1994 to 1996 CDF&G conducted quantitative surveys of large woody debris (LWD) in 64 streams in Mendocino and Humboldt counties. A total of 38 of the streams sampled by the state are located on PL's ownership or in adjacent areas. Data from these streams were used to analyze LWD conditions within the ownership. Additionally, PL has begun measuring LWD volumes and abundance in several portions of the ownership. Additional details on the collection and analysis of LWD data by the state are described in Volume IV Part D, Flosi and Reynolds (1994), and R2 (1997).

- **Hatchery Records.** Data on hatchery production and hatchery releases were provided by the Humboldt Fish Action Council (HFAC 1995), and from PL's internal hatchery records. Data for hatchery releases were organized by year and species.

- **Interviews with state regulators and local fisheries biologists.** R2 staff contacted and interviewed regulators with CDF&G, the North Coast Regional Water Quality Control Board (NCRWQCB), California Department of Forestry (CDF), and the National Marine Fisheries Service (NMFS). Researchers with Redwood National Park, Humboldt State University, the Humboldt Fish Action Council, and the Mattole Restoration Council were also contacted and interviewed.

- **GIS datasets previously compiled by PL.** PL owns an extensive GIS library containing data on road mileage/distribution, harvest history, stand condition, soil types, and other coverages that were used, as needed, for the MSHCP analysis.

Collectively, the above datasets provided information on stream habitat conditions, fish distribution and abundance, slope stability, soil erosion hazard, road density and type, harvest history, and vegetation characteristics. These data provide the basis for evaluating fisheries, stream channel, and some of the watershed conditions in each of the WAAs. Data collection efforts, particularly site-specific monitoring, are currently being conducted by PL and the state. Accordingly, the analysis presented here can and will be updated in the future as additional data, and particularly site specific data on management impacts to streams and fish, become available.

1.2.1. Stream Habitat and Water Quality Analysis Methods

Stream habitat results reported here focus on evaluation of overall conditions in each WAA. Consequently, data from specific areas within each WAA have been analyzed collectively at a broader, landscape level. This landscape level analysis is useful for: 1) determining conditions in WAAs, 2) making comparisons to conditions in other analysis units such as reference streams, 3) identifying regional or geographic patterns in the data, and 4) assessing whether WAAs with differing management histories show differences in stream conditions or fish populations. This last element is especially useful because it can identify WAAs that show evidence of cumulative effects from management activities.

A total of 15 habitat variables were examined (Table 1). The same general procedures were used to analyze all habitat variables:

- Data for individual habitat units (e.g., pools, riffles) were grouped by stream or, if more than one channel type was present, stream segment. Average values for each stream or segment were then determined.

- Average values for each variable were ranked such that the WAA with the best average value received a rank of 1, second best a rank of 2, etc.

- Values for each variable in each WAA were compared to criteria for good and poor habitat conditions. These criteria were developed by PL and R2 using published studies, discussions with regulatory staff, and professional judgement.

Data on sediment size (percent <0.84 mm, percent <4.7 mm, D_{50}), and water temperature were collected from monitoring stations on PL's ownership. For these data average values were determined for each WAA. However, temperature data from individual stations were also examined to determine where high water temperatures were present.

Data on large woody debris (LWD) levels were obtained from the state's LWD database. R2 converted reported values into pieces of LWD per 100 foot of active channel. As with the other habitat variables, average values for LWD abundance were determined for each WAA.

The stream habitat variables examined by PL were selected to provide two types of information, the condition of stream attributes important to fish, and the effects of timber management activities on aquatic resources. For example, data on the abundance and size of pools, instream cover, spawning gravel abundance and water temperatures can indicate how "good" stream habitat is within PL's ownership. By contrast, data on embeddedness, fine substrate, and canopy closure are sensitive to road construction, management induced landslides, riparian zone harvest and other management impacts. Whether to identify habitat quality, or management effects, the approach to identifying degraded conditions was to compare stream habitat conditions in each WAA to those in other study areas (unlogged reference streams, the Bioregion, and other WAAs) and to good and poor habitat criteria. The measurement and importance of each habitat variable, and the basis used to select good and poor habitat criteria are discussed below:

Rosgen Channel Type. This typing is based on the Rosgen (1994) method, using several measurements of the stream channel: channel width, channel depth, entrenchment, sinuosity, slope, and substrate. A channel is classified using a flowchart to identify the corresponding stream channel type as determined by the measured characteristics.

Mean Pool Depth. This quantitative estimate of habitat quality was determined by taking several depth measurements in each pool, then determining the average value for those measurements (Flosi and Reynolds 1994). Mean pool depth varies with stream size (i.e., small streams have small pools). However, regardless of whether pool depths are due to stream size, sediment loading rates, or other factors, low values for this variable are biologically important because pool depth is important in determining the amount of habitat available for juvenile salmonids during summer rearing periods (Nickelson et al. 1992), and adult salmonids during winter (Baltz et al. 1991). Reduced pool depths can also indicate increased sediment inputs to streams from management activities or natural processes. As sediment loading rates to streams increase, the mean depth of pools generally decreases.

Table 1. Summary of habitat and water quality variables analyzed within the Pacific Lumber Company (PL) Watershed Assessment Areas (WAAs)

Variable	Type of Data	Data Source	Importance	Relevance
Rosgen channel type	Qualitative	State habitat database	High	Indicator of geomorphic conditions.
Mean pool depth (ft)	Quantitative	State habitat database	High	Measure of sediment loading, indicator of slow, deep habitat for fish.
Maximum pool depth (ft)	Quantitative	State habitat database	Moderate	Measure of sediment loading, indicator of pool habitat for fish.
Residual pool volume (ft^3)	Quantitative	State habitat database	Moderate	Measure of sediment loading, indicator of slow, deep habitat for fish.
Embeddedness (%)	Qualitative	State habitat database	Moderate	Indicator of fine sediment; related to spawning, incubation and emergence success, and invertebrate production.
Percent fines < 4.7 mm (%)	Quantitative	State & PL monitoring	Moderate	Indicator of spawning, incubation, emergence success
Percent fines <0.85 mm (%)	Quantitative	State & PL monitoring	High	Indicator of spawning, incubation, emergence success, and invertebrate production.
Percent gravel dominance (%)	Qualitative	State habitat database	Moderate	Indicator of spawning, rearing, and cover substrates, and invertebrate production.
Maximum Weekly Average Water Temperature (°C)	Quantitative	State and PL monitoring	High	Indicator of fish health and distribution, and stream shading; influences species composition.
Macroinvertebrates (various measures)	Quantitative	PL monitoring	High	Indicator of stream productivity and food availability for fish.
Percent canopy (%)	Quantitative	State habitat database	High	Indicator of solar loading, index for LWD recruitment, source of organic carbon and invertebrates.
Percent pools (%)	Quantitative	State habitat database	High	Indicator of the quality of habitat available for fish.
Percent cover (%)	Qualitative	State habitat database	Moderate	Indicator of shelter present in the stream.
Large woody debris (# pieces/100 ft)	Quantitative	State LWD database	High	Indicator of shelter, and channel complexity/stability
Sediment D_{50}	Quantitative	State and PL monitoring	Moderate	Indicator of substrate size, invertebrate production

Mean pool depths were divided into three categories: 1) low (<1.0 ft), 2) moderate (1.0-2.0 ft), and 3) high (>2.0 ft). The high rating of greater than 2 ft is supported by Platts et al. (1983). In addition, McMahon (1983) describes deep pools suitable for coho parr as having depths greater than 1.8 ft. The low rating is based on the assumption that pools less than one foot deep lack the functions important to fish such as shelter from currents and predators. Support for this is provided by McMahon (1983) who found abundant coho parr in pools greater than 1 ft., but not in shallower habitats.

Maximum Pool Depth. This is a quantitative measure of the deepest part of each pool encountered during the state's stream habitat surveys. As with mean pool depth, maximum depth varies with stream size, generally increasing as stream size increases. Maximum pool depth is important to fish because it indicates whether pools have deeply scoured "pockets" that provide shelter from currents and predators. Pools with such pockets can provide excellent habitat for fish, even if the average depth for the entire pool is relatively shallow. By contrast, if both mean pool depth and maximum depth are low, then the value of the habitat is reduced. Maximum pool depth is also of interest because, as noted above for mean depth, it can indicate sediment deposition in pools.

The three categories used for maximum pool depth were: 1) low (<2.0 ft), 2) moderate (2-3 ft), and 3) high (>3 ft). The high value was taken from Steele and Stacey (1994). Further support for this high rating comes from the Knopp report (NCRWQCB 1993) that found maximum pool depths in excess of three feet throughout the North Coast, regardless of management history. The values for moderate (2-3 ft) were based on the assumption that maximum depth must exceed 2 ft to fully satisfy the habitat requirements of juveniles and adults.

Residual Pool Volume. This is the amount of wetted space that would remain in a pool under conditions of zero discharge. It is calculated as follows (from Flosi and Reynolds 1994):

(average pool depth [ft] - depth at pool tailout [ft]) * pool length (ft) * pool width (ft)

Subtracting the depth at the pool tailout (downstream end of pool) from average depth identifies how deep the pool would be under zero flow conditions when only water trapped within the pool would remain. This residual depth is then multiplied times the dimensions of the pool to calculate the residual volume. As with average and maximum pool depth, this variable shows a strong relationship to overall stream size.

Residual pool volume is of interest because it can be used to assess likely pool size for fish during summer critical low flow periods even if the habitat measurements are taken during a time of the year when higher flows, and therefore greater water depths, are present. As with the other pool measurements, its importance to fish is that it identifies the amount of deep water refuge from predators and currents that is available. Generally, higher values of residual pool volume would be considered better for fish. For example, Bjornn et al. (1977) found that the abundance of juvenile salmon in pools declined as the amount of pool volume decreased. In addition, the Knopp report (NCRWQCB 1993) found that residual pool volumes on the North Coast varied with management history, suggesting this variable has value for assessing management impacts.

The categories for residual pool volume used in this analysis were: 1) low (<200 ft^3), 2) moderate (200-600 ft^3), and 3) high (>600 ft^3). The Knopp report (NCRWQCB 1993) found values ranging from 236-483 ft^3 in North Coast streams. However, a review of data from PL's ownership and reference streams indicated that the values in the report were too low. Data for PL's ownership indicated that high residual pool volume was greater than 600 ft^3, which is how this value was chosen. Moderate levels were set to "capture" the range of values in the Knopp report (i.e., from 200-600 ft^3).

Embeddedness. This is the percent to which cobbles in the downstream ends of pools are surrounded or covered by fine sediment (Flosi and Reynolds 1994). This variable was estimated visually by the CDF&G, who recorded the following four ranges of embeddedness: 1) 0-25%; 2) 25-50%; 3) 50-75%; and 4) 75-100%. Evaluation of the state's data indicated that the majority of embeddedness values recorded by field observers were scores of 2 and 3. Discussions with CDF&G (S. Downie, CDF&G, pers. comm.) indicated that many field observations of embeddedness were approximately 50 percent, and that distinguishing between scores of 2 and 3 should be done with caution. We therefore aggregated embeddedness scores as follows: a low class for average embeddedness values less than 1.75 (approximately 44%), a moderate class ranging from 1.75 to 3.25 (approximately 45 to 80%), and a high class for average scores greater than 3.25 (approximately <80%). As noted, the moderate class was designed to encompass values of embeddedness above and below 50 percent. The high class was selected because Chapman (1988) found that coho salmon parr growth was reduced when embeddedness exceeded 80 percent. This selection of categories biases embeddedness results toward the moderate category.

Embeddedness provides some indication of the degree to which fine sediments have filled interstitial spaces between particles. High embeddedness values can therefore indicate that excessive sedimentation is taking place. This can have a variety of effects on fish and invertebrate populations including reductions in the suitability of spawning substrates (Chapman 1988), decreased survival of salmonid eggs and fry (Reiser and White 1988), and reductions in the abundance of the prey organisms used as food by fish (Bjornn et al. 1977).

Percent Fines (<4.7 mm). This is a measure of the percentage of the stream bed composed of particles less than 0.185 in., or 4.7 mm in diameter. As with the size fraction <0.85 mm, particles <4.7 mm were measured at monitoring stations to evaluate the quality of salmonid spawning gravel in streams within the study areas. Sediments <4.7 mm include many sands and fine gravels, which can cover and smother or entomb trout and salmon eggs and fry. Fines were measured using McNeil core samples (McNeil and Ahnell 1964) or shovel samples of gravel, that were then sorted by size, dried, and weighed.

Percent fines <4.7 mm were placed into three categories: 1) low (<20%), 2) moderate (20-50%), and 3) high (>50%). Literature values to set these category limits were not identified, so a frequency distribution of levels in streams from the CDF&G database was prepared. This frequency distribution was then used to assess the category values, with the high category set to include approximately 30 percent of all observations.

Percent Fines (<0.84 mm). This is a measure of the percentage of the stream bed composed of particles less than 0.034 in, or 0.85 mm in diameter. The fines levels were measured at monitoring stations to evaluate the quality of salmonid spawning gravel in streams within the study areas. Sediments less that 0.85 mm were selected because they have been examined in many studies of egg and fry survival (review in Chapman 1988). Fines were measured using McNeil core samples (McNeil and Ahnell 1964) or shovel samples of gravel, that were then sorted by size, dried, and weighed.

An increase in the percentage of fine grained sediments has been correlated with reduced salmonid embryo survival and fry emergence (Shepard et al. 1984; Reiser and White 1988; Young et al. 1991). These reductions occur for two reasons. First, as fines fill the interstitial spaces between gravel and cobble substrates, gravel permeability decreases to levels that impair salmonid embryo survival (Reiser and White 1988). Secondly, the filling of interstitial spaces can "entomb" fry, preventing them from swimming up through the gravels and into a stream's water column.

Percent fines were placed into three categories: 1) low (<20%), 2) moderate (20-30%), and 3) high (>30%). Support for the low category is provided by published studies that found percent fines in unmanaged streams in the Coast Ranges of Oregon and Washington of approximately 10-20 percent (Cederholm et al. 1981; Hatten 1991). In addition, data collected by PL indicate that values less than 20 percent are frequently observed in streams known to have high fish production (e.g., Lawrence Creek). Moderate values (20-30%) were selected based on the percent fines observed in the Freshwater drainage. Freshwater Creek has high fish production, and it is located in a geologic area with higher fine sediment production. Thus levels in the Freshwater Creek system were viewed as representative of conditions where, natural geology, in part, results in higher fine sediment loading, but fish production is still high.

Percent Gravel Dominance. Unlike most studies of stream habitat, CDF&G's work did not include measurements of the percentage of the stream bottom composed of each of several size classes of sediment. Instead, CDF&G recorded the particle size classes (e.g., sand, cobble, etc.) that were the most abundant and second most abundant at each pool tailout encountered (Flosi and Reynolds 1994). These data were used to calculate the percentage of all pool tailouts that were dominated by gravel substrates. For example, a value of 40 percent means that the dominant substrate in 40 percent of the pools examined was gravel.

Gravel dominance provides information on the abundance of the sediment size class most heavily used by spawning trout and salmon. Because this variable was measured in pool tailouts, it is especially useful for evaluating the abundance of spawning habitat because these areas are frequently used for spawning by trout and salmon.

As noted, quantifying gravel substrate dominance represents a non-standard approach to measuring substrate composition. Consequently, we were unable to identify literature based values to define high, moderate, and low values for this variable. For purposes of this study, three categories were selected as follows: 1) low (<20%), 2) moderate (20-50%), and 3) high (>50%).

Maximum Weekly Average Temperature. Temperature, used here, is the water temperature (°C) measured by continuously recording thermographs. These continuous temperature readings were used to determine the maximum weekly average temperature (MWAT) using methods in Brungs and Jones (1977) and Armour (1991). However, differences among the temperature records for each site, including frequency of sampling, and duration of temperature records indicate that caution should be used when directly comparing results among stations.

For this study, temperatures were categorized as high (MWAT>18.4°C) and low (<18.4°C) The categories were chosen based on a review of thermal tolerances in coho salmon and steelhead trout, additional details of which are provided in Volume IV Section D.

Macroinvertebrates. This is a quantitative estimate of the macroinvertebrate population in the sample area. Aquatic macroinvertebrates are collected using methods in the California Stream Bioassessment Procedures prepared by Jim Harrington of CDF&G. This methodology involves sampling riffle habitats using a kick net. Collected invertebrates are preserved in the field.

In the laboratory, the samples are subsampled, and the first 300 invertebrates are identified to family, and, where possible, to genus. The samples are identified by Lauck, Lee and Lauck Inc. Their results are used to calculate abundance (if less than 300), species richness (i.e., number of taxa), and the Simpson and Hilsenhoff diversity indices. Richness is a measure of the total number of taxa or groups of taxa. Taxa richness generally decreases with decreasing water quality. The most common measures of stream health are diversity indices. The Simpson diversity index is based on species dominance. This index produces values from 0 – 1.0. More diverse samples are associated with higher Simpson scores. The Hilsenhoff index is a biotic index that weights the relative abundance of each taxon in terms of its pollution tolerance to generate a community score. Generally the higher the score the poorer the water quality. PL's methodologies for the macroinvertebrate procedures have been reviewed by Jim Harrington, John Lee of Lauck, Lee and Lauck Inc. and Vincent Resh of UC Berkeley.

Percent Canopy. This is a quantitative measure of the amount of overhead area that is occupied by vegetation, regardless of the type or density of that vegetation. It was measured by CDF&G staff with an instrument called a spherical densiometer using methods outlined in Flosi and Reynolds (1994). This variable is strongly correlated with stream size; as stream size increases the canopy closure decreases because of increased channel width.

Percent canopy was analyzed because it can be used to determine the impact or influence of several other factors. First, canopy closure over streams is a good measure of potential solar loading. Solar loading, in turn, is related to the potential for high water temperature. Secondly, canopy closure is also a qualitative index of the potential for large woody debris (LWD) recruitment to a stream (WADNR 1994). Stream segments with low canopy closure have a reduced potential for LWD recruitment. This can negatively impact habitat diversity and quality for salmonids through reduced pool frequency and depth, lower cover levels, and poor spawning gravel retention (see discussion for percent cover). Finally, canopy within the riparian corridor is an important source of organic carbon and terrestrial insects to the stream system. These energy sources are part of the food web that supports fish and aquatic invertebrate populations.

Canopy levels were categorized as: high (70-100%), moderate (45-70%), and low (<45%). Several lines of evidence support our delineation of high canopy closure as levels that exceed 70 percent. First, it may not be possible to attain higher levels in most North Coast streams. A review of data from the CDF&G database indicates that even completely forested streams (e.g., South Fork Freshwater Creek) have canopy levels less than 90-100 percent. Similarly, a review of five unmanaged streams in Humboldt Redwoods State Park found values ranging from 70-80 percent in all but one stream (which had 48%). Second, canopy closure levels above 70 percent may actually have adverse effects on fish production because of reductions in water temperature, and solar radiation. For example, Pearson et al. (1970) found that coho fry avoided stream sections with the greatest shading levels, and several studies have noted increases in aquatic productivity, including increases for coho salmon or steelhead trout, at lower canopy levels (Chapman and Knudsen 1980; Murphy and Hall 1981; Murphy et al. 1986; Thedinga et al. 1989; Carlson et al. 1980). Finally, several studies have identified canopy closure levels of 70-80 percent as optimal (Oregon-Washington Interagency Wildlife Conference [OWIWC] 1979; McMahon 1983). Values for moderate and low canopy closure were based on professional opinion, and on studies citing canopy levels less than 50 percent as sub-optimal (OWIWC 1979; McMahon 1983).

Percent Pools. This variable is equivalent to the state of California's "percent total length." This quantitative variable represents the total stream length composed of pools divided by the total length of all habitat types multiplied by 100.

Percentage pools was examined because it is widely recognized as a good index of habitat quality for coho salmon (Heifetz et al. 1986; Lisle 1986; Bilby and Ward 1989). Percentage pools has also been strongly correlated to densities of coho parr in streams (Peterson et al. 1992). In addition, as with the other pool variables discussed above, the variable percentage pools is sensitive to sediment inputs, generally decreasing when sediment inputs increase (Lisle 1981).

Percentage pool habitat was categorized as: 1) low (<25%), 2) moderate (25-40%), and 3) high (>40%). Several studies support delineating the high category as any frequency above 40%:

- The Knopp report for the NCRWQCB concluded that the percentage of pools along the coast was less than 50 percent, ranging from about 37 percent in unmanaged (i.e., unlogged and unroaded) systems, to the low to mid 40s in managed systems (NCRWQCB 1993).

- Observations in Oregon streams by Carlson et al. (1980) showed that pools in unmanaged systems ranged from 12 to 39 percent.

- A review by Peterson et al. (1992) indicated that pool percentages in unmanaged systems vary widely and decrease with stream gradient. Of nine studies reviewed throughout a broad geographic range, pools averaged 36 percent in unmanaged streams.

The moderate and low ratings were based on our review of values for stream segments on PL's ownership, and in unmanaged, reference streams. In general, we found that most reference streams and stream segments recognized as having good anadromous fish runs (e.g., Elk Creek, Freshwater Creek) fell within a range of 25 percent or greater. Consequently, values less than 25 percent were categorized as low.

Percent Cover. As used here, instream cover is the total percentage of the stream channel containing undercut banks, small woody debris, large woody debris, terrestrial vegetation, aquatic vegetation, entrained bubbles, and boulders. Percent instream cover was visually estimated during the state's habitat surveys.

Percent instream cover is important because it is often used as an indicator of the amount of shelter that is available to fish in a habitat unit (Bustard and Narver 1975a, 1975b; Heifetz et al. 1986; Shirvell 1990). Shelter, from both predators and from high water velocities, in turn, can increase the survival or growth of fish. Cover, particularly large woody debris, can also lead to increased densities of salmonids when compared to stream reaches with little or no cover (Bryant 1983; House and Boehne 1986). This increase in density has been observed for both trout (Bisson et al. 1982) and coho salmon (McMahon and Hartman 1989). McMahon and Hartman (1989) also found that deep, slow water habitats, such as pools, were only important to coho as wintering areas when found in conjunction with cover providing three-dimensional complexity.

Categories used for instream cover were: 1) low (<20%), 2) moderate (20-40%), and 3) high (>40%). The state's methodology of estimating cover visually, and without supporting measurements, is not commonly used among fisheries scientists. Accordingly, literature values to support these categories were not identified. Instead, a frequency distribution for the cover ratings from all streams within the bioregion, PL's ownership, and from unlogged reference streams, was plotted. This distribution indicated that cover values range from zero to approximately 50 percent, with most observations falling between 10 and 20 percent. These are low values so the categories were chosen to reflect this. The selected value for high (<40%) results in the exclusion of nearly all stream segments from this category, and is, therefore, conservative. Moderate values were selected to include the upper end of the frequency distribution. The low category contains the majority of the observed values (approximately 60%).

Large Woody Debris. The measure of LWD used here came from the state's LWD database. This dataset was compiled by subsampling portions of streams and rivers in California, including a number on PL's ownership. During these surveys all wood pieces longer than 6 ft, and greater than 12 in. in diameter and located in the active channel were counted. These counts, expressed as number of pieces/100 ft of stream, are reported here.

Woody debris is important for the production of trout and salmon. Numerous studies have demonstrated the importance of LWD to anadromous fish (Bustard and Narver 1975a, 1975b; Bisson et al. 1982; Tschaplinski and Hartman 1983; Heifetz et al. 1986; Murphy et al. 1986; Holtby 1988, McMahon and Hartman 1989; Shirvell 1990). LWD benefits fish because it produces habitat characteristics important for fish survival and growth including scour pools, cover, and gravel deposits (Powell 1988; USDA 1993). In addition, LWD stabilizes stream channels, and can help retain leaves and other organic debris that provide inputs to the aquatic food chain (Powell 1987; Holtby 1988; Bilby and Bisson 1992).

We did not attempt to set good and poor criteria levels for LWD for several reasons: 1) the state's database is currently too small, and does not include enough streams with little or no management history, to determine high, moderate, and low levels using a frequency distribution of observed LWD levels; 2) measurements and definitions contained in published studies of LWD vary enormously making extrapolation from these studies to the state's results difficult; and 3) no LWD results were available for 2 of the 5 WAAs being analyzed.

Sediment D_{50}. Values reported here are the diameter of the median sediment size, or D_{50}, in millimeters. If all the individual particles within a sediment sample were measured, _ of all particles would be bigger, and _ would be smaller than the D_{50}. In practice, the D_{50} is determined by plotting the cumulative frequency distribution of sediment size for samples collected from monitoring sites.

The D_{50} is another measure of the size characteristics of substrate. A small D_{50} indicates that at least half of the substrate at a given site is composed of fine sediment which, as noted for the fine sediment variables above, can reduce spawning success and invertebrate production. Conversely, a large D_{50} suggests that fine sediments are not an important problem in a given sampling area. Criteria for good and poor D_{50} levels were not identified since these levels are quite variable between streams. The target for this measure is to maintain or increase the D_{50} at each station.

1.2.2. Fisheries Data Analysis Methods

A comprehensive survey of the distribution of anadromous fish within the study region has not been conducted (Jim Hopelain, CDF&G, pers. comm.). Consequently, data to definitively determine fish distributions are not available. However, results from many stream specific surveys (electrofishing, redd, and/or carcass) are available and can be used to identify locations that have contained each salmonid species in the past ("record of presence"). These records of presence were mapped, then extended upstream to the location of fish passage barriers, if known, or to the headwaters of the drainage containing the record of presence. Presence information was also obtained from PL biologists, and used to modify the map of fish distribution, as needed.

Definitive data to assess adult and juvenile abundance are also not available. In general, quantitative data on adult escapement levels have not been collected (however, see HFAC 1995), and the timing and methodology used for redd and carcass surveys by the state prevent the use of these data to make accurate population estimates for adults. Recent monitoring data collected by CDF&G include estimates of juvenile, and in some cases, adult abundance. These data will provide more conclusive evidence of fish abundance in the future.

The state has collected some quantitative data on juvenile abundance, but in most cases these data were limited to records for a single census in each stream. These census efforts occurred from 1989 to 1996. Although some census efforts involved multiple electrofishing passes and were therefore amenable to depletion estimates of abundance, most sites were censused with only one or two passes. Population estimates from single pass electrofishing surveys frequently result in significant underestimates of true population size. In addition, there were differences in the timing of the census efforts, which, because of migration, seasonal mortality, or growth could lead to differences in fish abundance, and in the observers' ability to differentiate among trout and salmon species (Scott Downie, Jim Hopelain, CDF&G, pers. comm.) Thus, to limit the bias due to timing or identification errors, juvenile abundance data from all passes and for all species were combined into a single estimate of juvenile salmonid abundance for each site.

Data from both CDF&G's redd and juvenile fish surveys were also used to quantitatively assess anadromous fish abundance. Specifically, these data were used to identify the general distribution and relative abundance of redds and juveniles in each WAA.

1.2.3. Methods to Assess Management Risk Factors

Risk factors, as used here, are conditions within each WAA that increase the likelihood that PL's timber management activities will negatively affect aquatic habitats, water quality, or fish production. Logging, road building, and other management activities affect streams by changing the rate of movement into, or "flux," of materials from upslope areas (Steele and Stacy 1994; WADNR 1994). In particular, management activities increase the flux of sediment and solar energy, and decrease the flux of large woody debris into streams. These changes in flux rates can lead to alterations in stream morphology and water quality that, in turn, alter the suitability of streams for fish production. Risk factors then relate to the likelihood that management will produce significant changes in flux rates.

Within each WAA, the risk factors slope, soil type, vegetation age and density, road density and surfacing, and road proximity to streams were determined for PL owned lands. This analysis is only a "coarse" assessment. PL intends that more accurate and detailed studies of risk factors will be conducted as part of its watershed analysis program (see Volume IV Part D). The importance and rating of each of the risk factors used here to assess the potential for PL to negatively impact streams is as follows:

Slope. The likelihood of landslides and other types of mass wasting generally increases as slope increases. In addition, sediments dislodged by surface erosion are more likely to be transported downhill to stream areas when slopes are great. Consequently, road building and harvest are most likely to affect the flux of sediments when slopes within a watershed are high.

Shallow seated landslides on PL's lands are generally found on slopes greater than 65% (PWA 1998a, 1998b). The analysis here assumed that slopes greater than 65-70 percent are at high risk of failure or erosion. Slopes from 40-70 percent were assumed to have moderate risk based upon our professional judgement. Slopes within each WAA were quantified using a geographic information system. The analysis of slope data was limited to lands within each WAA that are located on PL's ownership.

Soils. Unstable or easily erodible soils are more likely to fail or erode. Consequently, management activities on these soil types are more likely to increase sediment flux rates. Although all soil types within the North Coast are unstable compared to most soils in areas such as the Sierra Nevada, the Humboldt WAA contains especially unstable and erodible soil types. Both soil characteristics, and the state's erosion hazard rating system (CCR 912.5) were used to assess soil risk.

The PL ownership is dominated by Hugo and Larabee soils. High elevation portions of the ownership also contain Atwell soils. The Hugo soil series is a well drained, loamy to clay soil typically 30 to 60 in. deep (Winzler and Kelly 1980). The well drained nature of Hugo soils make them less prone to mass wasting. The Larabee soil series has developed from tertiary marine rock and other local soils. Although landslides are common in this soil type, studies indicate that is it not the dominant source of sediment in streams within PL's ownership (Winzler and Kelly 1980). The Atwell soil series has developed on weathered, sheared sedimentary rock. Areas in the Atwell soil series are considered highly unstable and appear to be the source of most suspended sediment within ownership streams (Winzler and Kelly 1980).

Risk levels for each WAA were based on the degree to which Atwell soils were present, and on the state's erosion hazard ratings. WAAs containing more than 10 percent Atwell soils, and/or moderate or high erosion hazard ratings were used to assign moderate and high risk for soils.

Vegetation Age and Density. Tree roots bind soil particles together. This tends to reduce shallow landslides and surface erosion. Trees can also decrease soil moisture levels through evapotranspiration, which also tends to reduce mass wasting. Finally, vegetation of all types disperses the energy of falling raindrops, which decreases the likelihood of soil erosion. For all these reasons, watersheds with older, denser forests are less likely to experience changes in sediment flux rates than are watersheds with a high proportion of young forest or grasslands.

Harvest history across PL's ownership varies widely. Some areas such as the Humboldt WAA have remained relatively unmanaged since the early 1900s, while other areas, including the Yager and Van Duzen WAAs, contain large areas that are actively being harvested, or that have been harvested in the recent past. Several WAAs, particularly the Yager and Bear-Mattole WAAs, also contain large areas with prairie vegetation. The analysis here assumes that high vegetation risk is associated with 50 percent or more of PL's lands within a WAA being composed of young forest or forest openings. Moderate risk is assumed to occur when these vegetation types are present in 30-50 percent of PL's ownership within a WAA. These risk levels were based on our professional judgement after examining site specific responses to harvest intensity in several areas of PL's ownership. These values were revised downward if off-ownership WAA lands include significant acreage in prairies.

Road Density/Surfacing. Many studies have shown that a majority of the surface erosion and mass wasting in watersheds originates from roads (see review in WADNR 1994). Although recent studies on PL's lands (PWA 1998a, 1998b) indicate that roads represent less than 20 percent of all sediment delivered to streams, this work confirms that roads are an important sediment source. Consequently, as the density of roads in a watershed increases, the likelihood of erosion and mass wasting also increases. Similarly, paved roads are less susceptible to erosion than are graveled roads, which, in turn, are less prone to erosion that dirt roads. Surfacing was therefore considered in assessing road related risk.

Assessing risk associated with roads is complicated because the likelihood that roads will contribute sediment to streams varies with a large number of factors including construction (e.g., cut and fill, full bench, etc.), frequency and type of water collection facilities, surfacing, the intensity and seasonality of use, proximity to streams, and maintenance (Weaver and Hagans 1994). Given this complexity, the demonstrated importance of roads in changing sediment flux rates to streams (WADNR 1994), and the recognition that some of PL's roads are vulnerable to erosion and failure, it is important to assess potential impacts of roads in more detail than is discussed here. Accordingly, PL has proposed to undertake detailed stability and erosion evaluations as part of its road storm proofing program. Risk levels associated with these road density/surfacing were subjectively assigned based on conditions in each WAA relative to those in the other WAAs.

Road Proximity. Whether sediment from road related erosion and mass wasting actually affects loading rates to streams depends, in part, on how close the roads are to streams. The smaller the distance, the greater likelihood that the roads will deliver sediment to aquatic systems. Risk levels associated with road proximity were subjectively assigned based on conditions in each WAA relative to those in the other WAAs.

Within each WAA, the risk ratings for these variables were combined to determine the relative likelihood that natural or management related factors are impacting aquatic environments. Based on this analysis, and on habitat and fisheries conditions in each WAA, areas of management concern, and possible mitigating actions, were identified.

1.2.4. Quality Assurance/Quality Control

During data reduction and analysis, quality assurance/quality control (QA/QC) procedures were used with the state's data (i.e., fisheries, habitat, and LWD data) to ensure the accuracy of both the original data, and the data transfer and conversion process. QA/QC procedures included a review of original database files, identification of errors (such as missing values), and the use of various procedures to correct errors and/or exclude questionable data. A subset of the analysis results was also compared to the original datasets to ensure accuracy. To ensure consistency, QA/QC was performed using standardized procedure data forms to record all actions taken.

1.3. DATA LIMITATIONS

The amount of stream habitat and fisheries data used for the development of this appendix, and of the MSHCP measures proposed by PL, exceeds that included in recent multi-species HCPs for other ownerships (e.g., Plum Creek 1996; Weyerhaeuser 1996). However, it is still important to acknowledge limits in both the data available and the analyses performed. These limits are summarized below:

- The CDF&G's juvenile abundance data were not collected systematically, so data are available for multiple dates for some streams and not at all for others. Similarly, the length of stream examined during the surveys varied. In addition, there is uncertainty in some of the species identifications made in the field, especially related to steelhead trout versus rainbow trout.

- CDF&G's redd surveys also were not conducted systematically. In some cases more than one census was conducted in a stream within the same winter. In such cases census efforts subsequent to the initial survey did not attempt to differentiate between new redds, and those that existed during the previous census effort (Jim Hopelain, CDF&G, pers. comm.). Consequently, summing the number of redds seen among census periods could lead to an overestimation of the total number constructed. In these instances data were used from only one census period in each stream each year (highest reported value was used), providing for a conservative estimate of the total number of redds.

- The state habitat database has several constraints or conditions that limit its utility, including:

- Some of the staff that collected the data had limited fisheries experience. Consequently, results for qualitative variables (i.e., those requiring some subjective decisions) may suffer from greater observer bias than would normally be expected (Scott Downie, CDF&G, pers. comm.).

- Some important variables such as substrate composition and embeddedness were not measured in the field using standard stream assessment methods. This makes it difficult to compare these data to the results of other, published work.

- The data collection program was not specifically designed to examine the impact of timber management. Instead, it was designed to identify possible watershed restoration sites within Humboldt County. Consequently, some variables that would be useful for this analysis (e.g., fine sediment levels) were not examined.

- Monitoring data are collected from discrete sites so conditions in stream segments outside the sampling areas were not known. However, given the mobility of fine sediments and macroinvertebrates, and the continuity of water temperatures along short distances in streams, it is reasonable to assume that data from each monitoring site were indicative of conditions in portions of the streams adjacent to the monitoring locations. However, monitoring data may not be applicable to other, more distant stream segments.

- Although datasets provided by PL to regulating agencies have included information for specific stream segments, R2's previous analyses of fisheries and aquatic habitat focused on an evaluation of overall conditions in each of the five WAAs. This emphasis on overall conditions within the WAAs is retained here.

1.4. SUMMARY OF RESULTS

1.4.1. Stream Habitat Data

Comparisons of stream habitat variables among PL's WAAs revealed that study areas contained a wide range of habitat conditions. Detecting differences among groups was difficult in some

Table 2. Average values for stream habitat conditions in the Pacific Lumber Company (PL) Watershed Assessment Areas. Values within parentheses represent the rank with 1 being the best observed and 5 the worst.

Stream Habitat Variable	Criteria[1]	Yager WAA	Humboldt Bay	Bear-Mattole WAA	Van Duzen WAA	Eel WAA
Mean Pool Depth (ft)	>2.0 ft/<1.0 ft	1.67 (1)	0.85 (5)	1.27 (2)	1.2 (3)	1.19 (4)
Maximum Pool Depth (ft)	>3.0 ft/<2.0 ft	2.96 (1)	2.11 (5)	2.34 (2)	2.3 (3)	2.24 (4)
Residual Pool Volume (ft^3)	>600 ft^3/<200 ft^3	1810 (1)	360 (5)	363 (4)	511 (3)	876 (2)
Embeddedness Score[3]	<1.75/>3.25	2.51 (1)	2.61 (3)	2.91 (5)	2.54 (2)	2.71 (4)
Percent Fines (<4.7 mm)	<20%/>50%	36.4 (3)	26.6 (1)	35.3 (2)	43.4 (5)	39.7 (4)
Percent Fines (<0.85 mm)	<20%/>30%	16.6 (1)	26.6 (4)	18.3 (2)	29.0 (5)	23.8 (3)
Percent Canopy	70-100%/<45%	50 (4)	76.1 (1)	15 (5)	68 (2)	54 (3)
Percent Pools	>40%/<25%	22 (3)	45 (1)	15 (4)	14 (5)	23 (2)
Percent Cover	>40%/<20%	20 (1)	17 (3)	11 (5)	17 (3)	17 (3)
Percent Gravel Dominance	>50%/<20%	45 (1)	35 (4)	33 (5)	38 (3)	41 (2)
Large Woody Debris (LWD) (pieces/100 ft)	ND[2]	5.6 (1)	5.5 (2)	ND[2]	ND[2]	1.3 (3)
Maximum Weekly Average Temperatures (MWAT)	≤18.4°C	16.1 (3)	15.6 (2)	18.3 (5)	15.4 (1)	17.1 (4)
Sediment D_{50} (mm)	ND[2]	93 (1)	57 (5)	64 (3)	60 (4)	88 (2)

[1] These values indicate the criteria for good and poor habitat conditions, respectively.
[2] Indicates no data or criteria available for this variable.
[3] Measured by State using nonstandard methodology (see Flosi & Reynolds 1994).

Contacts with other fishery researchers indicated a concern that the Yager WAA had excessive sedimentation levels from management activities. Examination of aerial photographs back to 1949 documented past widening of both Yager and Lawrence creeks, coincident with and following timber harvest. Such widening is strong evidence for increases in sediment loading rates. However, at least some of the increase in stream widths was related to bank erosion associated with streamside harvest and cross channel yarding.

In addition, photos from the past 10-15 years show channel narrowing, and riparian vegetation growth consistent with recovery from these impacts (Figure 1-1). As noted above, values for embeddedness, fine sediment, and pool depth, all variables sensitive to sediment loading rates, were similar to or better than those in other study areas. Collectively, these data suggest that the Yager WAA experienced an increase in sediment loading rates, but that recovery has led to current conditions that are similar to those in less intensively managed areas.

An important fisheries problem within the WAA is locally high water temperatures. Temperatures at some monitoring stations within this WAA reach higher levels than have been observed in any of the other WAAs. In places, such as the North Fork of Yager Creek, they exceed levels (>25.0°C) that are acutely lethal to trout and salmon. The problem is at least partly related to the high proportion of the WAA composed of prairie habitats, a habitat type associated with high thermal loading. Strong evidence for this comes from Burns (1972) who recorded high water temperatures in the South Fork of Yager Creek even though the entire forested part of this drainage still consisted of old growth redwood forest. However, the mean percent canopy in the Yager WAA is relatively low (50%), which permits thermal loading of streams even after they cross onto PL's ownership. Because Yager and Lawrence creeks are relatively large, low canopy levels in these drainages are expected, and an analysis of aerial photographs documented wide stream floodplains in these creeks before logging began. However, it is also clear that historic logging of streamside trees in the WAA has exacerbated the problem with low canopy levels.

Overall, conditions for trout and salmon production in this WAA are good, but site visits indicate that instream cover, and, in places, temperature, are limiting factors. Low instream cover and canopy levels, combined with locally elevated high temperatures, indicate that the primary management concern is harvest of streamside vegetation. In addition, this WAA needs to be monitored to ensure that intensive timber harvesting over the last decade does not lead to a future degradation of habitat conditions (see Volume IV Part D on cumulative effects).

Van Duzen WAA

Limited habitat information is available for the Van Duzen WAA relative to most of the other areas studied. Therefore conclusions based on the habitat studies to date must be viewed with caution. The existing data indicate that this WAA had the worst observed values for percent fines <0.84 mm, and <4.7 mm, and percent pools. Conversely, water temperatures were lower and percent canopy values higher than in most other WAAs. Pool depth and volume, percent cover, and gravel dominance were all at intermediate levels relative to the other WAAs.

Overall, fish in this WAA are likely to suffer from limited deep water habitat, and poor spawning and invertebrate production resulting from the abundant fine sediments. However, shading and good water temperatures should provide habitat for temperature sensitive species such as coho salmon, that may not be able to tolerate higher temperatures noted in other parts of the ownership.

Eel WAA

This WAA contained low average values for mean and maximum pool size, and had high embeddedness, fine sediment levels (<4.7 mm) and water temperatures. Conversely, values for D_{50}, gravel dominance, percent pools, and residual pool volume were better than in most other WAAs. Low mean and maximum pool depths, combined with high residual pool volumes indicates that the WAA contains large but shallow pools. Large, shallow pools, combined with higher embeddedness and fine sediment levels suggest that some streams within the Eel WAA are currently experiencing sediment infilling of deep water habitats important to fish.

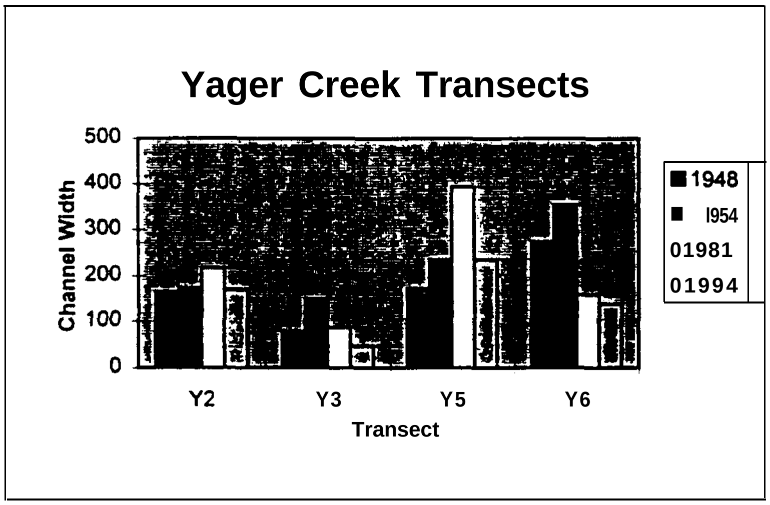
Temperature conditions within the Eel WAA vary. At many monitoring sites the temperatures are consistent with the thermal regime preferred by salmonids. Conversely, acutely lethal temperatures have been recorded in Larabee Creek, although poor probe placement and maintenance raise questions about the accuracy of this result. Low canopy cover levels along Larabee (<45%) are consistent with high water temperatures. In most other portions of the WAA the percent canopy levels are moderate and similar to that in the study areas.

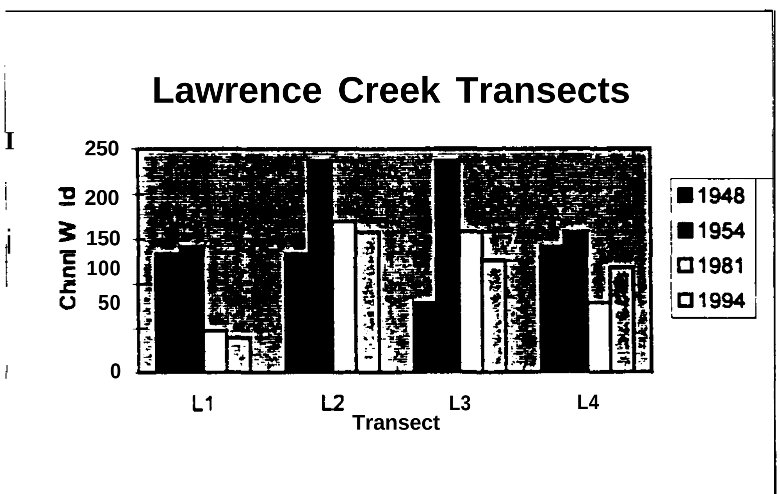
Habitat data for this WAA are mixed. This WAA appears to rank poorly compared to most other WAAs because many of the average habitat values were low (i.e., rank of 4) and few were high (e.g., none with a rank of 1). However, a number of habitat variables were at the second best levels observed among the WAAs. Overall, it appears that high fine sediment levels and temperatures and abundant but shallow pools could limit trout and salmon production in many streams in this WAA.

Bear-Mattole WAA

Less habitat information is available for this area than for any other WAA. Therefore, conclusions based on the habitat studies to date must be viewed with caution. Existing data indicate that this WAA had the lowest or second lowest average values for percent canopy, percent pools, instream cover, percent gravel dominance, and the highest values for embeddedness and water temperature. However, mean and maximum pool depths and percent fines were better than those in most of the other WAAs. Consequently, it does not appear that pool filling or degradation of spawning gravels, which would be expected at high sediment loading rates, is prevalent. Both low canopy and high water temperatures indicate that thermal stress to fish could be a problem in this WAA. In addition, low canopy and instream cover levels suggest that LWD levels in the study streams were low and the abundance of hardwood forest types in this WAA would be expected to limit the size and instream persistence of LWD that is recruited to streams in the future.

Figure l-l. Changes in channel width from 1948 to 1994 for select transects on Yager and Lawrence creeks, California.





The limited data available indicate that conditions in this WAA are likely to be the most adverse with respect to production of trout and salmon. Poor pool abundance and volume, high sediment levels, and high temperatures are all present in this area, indicating that a number of habitat problems exist in the streams of this study area.

Considering all WAAs, it is clear that instream cover is one of the factors most likely to be limiting fish production on PL's ownership. Although criteria for LWD were not developed for this analysis, analysis of LWD on the ownership (R2 1997) indicate that low levels are present in most areas, which could help explain low instream cover. High sediment levels, and small, infrequent pools were also commonly observed problems among the WAAs.

The problems with stream habitat noted above, where present, are not necessarily unique to PL's ownership. Values for stream habitat variables measured by the state in PL's WAAs were comparable to those in other streams within the bioregion surrounding PL's ownership (R2 1996a). In addition, several studies indicate that high sediment levels and water temperatures are a natural part of the ecology of streams in the north coast region of California (Burns 1970, 1972, R2 1996b). For example, a high percentage of fine sediments is likely linked to the unstable geology within the study area. Likewise, shallow pools in several WAAs may be due to the smaller size of streams within these study areas. Finally, high temperatures and low canopy cover are related, in some cases, to the naturally greater width of larger streams like Yager and Lawrence creeks.

1.4.2. Analysis of Habitat/Management Relationships

Two linear regressions (least squares methodology) were calculated to assess whether the intensity of management activities in each WAA could explain observed sediment values. A third regression tested whether temperature and watershed size were related. Specifically, the regressions included:

- Percent fine sediment <0.85 mm versus PL's calculated Disturbance Index
- Percent fine sediment <0.4.7 mm versus PL's calculated Disturbance Index
- Maximum Weekly Average Temperature versus Watershed Size (acres)

Values for sediment and MWAT were for individual monitoring stations. Values for the Disturbance Index and watershed size were calculated for the watershed upstream of each monitoring station as calculated using PL's GIS system. The Disturbance Index evaluates road density, acres harvested, and harvesting method to estimate total disturbance levels within each WAA.

The regressions indicated that the disturbance index and observed sediment levels were not correlated. The coefficient of determination (r^2) for fines <0.85 mm and <4.7 mm were 0.01 and 0.006 respectively. The very low r^2 values indicate a strong non-correlated relationship for the two sediment/disturbance index evaluations.

Conversely, water temperature and watershed area did appear to be correlated, with an estimated r^2 value of 0.51. The limited number of points at the upper end of the regression (i.e., for watershed areas greater than 10,000 acres) and the moderate r^2 value indicate some ambiguity regarding the strength of this relationship. However, plots of the MWAT/watershed area data clearly show that no watershed less than 9,000 acres exceeded the criterion for the MWAT (i.e., 18.4°C), whereas 4 of the 5 stations with watershed areas larger than 9,000 acres did. Increased watershed area would be expected to result in larger, wider streams. Trees along such streams would be less effective in providing shade, which could explain the observed relationship between watershed area and MWAT.

1.4.3. Fisheries Data

A general summary of data on the abundance, distribution, and types of fish present in each WAA is presented below. More detailed discussions of fisheries resources in PL's ownership are included in Section 2.

Humboldt Bay WAA

Analysis of fish population information indicates that salmon and trout are present in the majority of streams sampled within the Humboldt Bay WAA. The state's redd counts indicate that adult fish are found in higher numbers within this WAA than in the other areas studied; redd counts were above 100 observations in several streams surveyed within the WAA. Other ongoing studies of juvenile abundance and adult escapement (e.g., HFAC 1995) have shown this WAA to contain large populations of coho salmon. Despite year to year variability in abundance, overall fish population information suggests that the Humboldt Bay WAA contains healthy fish populations.

Yager WAA

Analysis of fish population information indicates that salmon and trout are present in the majority of streams sampled within the Yager WAA. Although fish sampling was generally qualitative, a sampling site on Lawrence Creek contained a higher density of juvenile salmonids (630 fish/1,000 ft^2) than was observed in any other sampling location. Considering all sampling sites in the WAA, juvenile salmonid abundance is similar to or higher than levels observed in the other WAAs. Redd counts indicate that the WAA is also an important site for spawning by salmon and steelhead trout. Counts within Lawrence Creek and its tributaries were among the highest observed (>40 redds) in any study area.

Van Duzen WAA

Analysis of fish population information indicates that salmon and trout are present in the majority of the streams sampled within the Van Duzen WAA. Juvenile salmonid abundance results were generally good, with the highest number of fish observed in Grizzly Creek (69 fish/1,000 ft^2). Redd counts indicate that adult fish utilize some streams within the WAA, but the limited number of sites censused by the state makes it difficult to generalize about adult use of the WAA. Overall, the available data indicate that the Van Duzen WAA contains at least some areas with productive fish populations.

Eel WAA

Analysis of fish population information indicates that salmon and trout are present in nearly all of the streams sampled within the Eel WAA. Although fish sampling was generally qualitative, high levels of juvenile salmonid abundance were frequently observed (e.g., Monument Creek contained 65 fish/1,000 ft^2). Redd counts indicate that adult fish are abundant in some streams within the WAA, but are limited in others. Overall, fish population information suggests that many streams in the Eel WAA contain productive fish populations, but other streams have limited value.

Bear-Mattole WAA

Fish population data for streams within the Bear-Mattole WAA are very limited. However, analysis of the minimal information gathered indicates that salmon and trout are present in some streams within the WAA. Juvenile salmonid abundance was reported for three streams. Juvenile fish were observed (31 fish/1,000 ft) in one of the three creeks. Redd counts have documented some adult spawning in the WAA as well. However, the absence of juveniles in two of the three creeks examined, and the low numbers of redds observed, do not suggest that the WAA contains large, or widely distributed anadromous fish populations.

1.4.4. Management Risk Factors

Results for risk factors are summarized in Table 3. Detailed discussions of risk factors in each WAA are provided below:

Table 3. Summary of WAA specific risk factors.

WAA	Slope	Soil	Vegetation	Roads	Overall Risk
Yager	low	low	high	high	moderate
Humboldt Bay	low	low-moderate	low	moderate	low
Eel	high	moderate	low	low-moderate	moderate
Van Duzen	low	low	moderate	moderate-high	moderate
Bear-Mattole	high	moderate	moderate	low	moderate

Humboldt Bay WAA

Slope classes within the Humboldt Bay WAA are generally in the 16 to 30 percent and in the 31 to 40 percent class. Less than 2 percent of the WAA contains slopes in excess of 70 percent. These low values indicate that the slope risk factor for the WAA is low.

The Humboldt WAA contains soils in the Larabee, Hugo, and Atwell series. The majority of the WAA is in the Larabee series, with Hugo soils the second most common. The upper portion of the WAA contains Atwell series soils. These areas have a high potential for soil erosion. The majority of the WAA (80%) has a low soil erosion hazard rating. The low ratings are due to the presence of moderate to low slopes within this WAA. Considering both soil type and the state's erosion hazard rating, this WAA has a low-moderate risk for soils.

The Humboldt Bay WAA within PL's ownership is dominated by late seral forest (42%). Late seral stage vegetation is primarily located in the northern and western portions of the WAA. Mid-successional stage vegetation is also located throughout the WAA with the largest concentration located in the central-eastern area of the region. Only 24 percent of the WAA is composed of young forest or forest openings. The overall vegetation risk for this WAA is therefore low.

The Humboldt WAA within PL's ownership contains 4.12 road miles/square mile. This is the second highest road density of any WAA. The majority of the roads (62%) within the Humboldt Bay WAA are unimproved dirt roads. There is a mainline gravel road in close proximity to portions of the North Fork Elk River. Some tributary streams to the N.F. Elk are also paralleled by gravel or dirt roads. There is a paved road in close proximity to points along Freshwater Creek. There are also dirt roads that are in close proximity or adjacent to tributaries to Freshwater Creek. The central portion of the WAA on PL's ownership contains no roads. Considering all factors, the road related risk for this WAA is moderate.

Yager WAA

Slope classes within the Yager WAA are generally in the 16 to 30 percent class and the 31 to 40 percent class. Less than 2 percent of the WAA contains slopes in excess of 70 percent. These low values indicate that the slope risk factor for the WAA is low.

Hugo is the primary soil series within the Yager WAA. The dominance of this soil type indicates that in general, soils within the WAA are well drained and less prone to mass wasting. The majority of the Yager WAA (85%) also has a low soil erosion hazard rating. Considering both soil type and the state's erosion hazard rating, this WAA has a low risk for soils.

The Yager WAA within PL's ownership is dominated (44%) by young forest. An additional 13 percent of the WAA is composed of forest openings. Areas of young forest are generally located in the Lawrence Creek drainage and the upper portion of the mainstem of Yager Creek. There are some areas of late seral stage forest throughout the WAA including the lower and middle portions of the mainstem of Yager Creek. Given the high percentage of young forest and forest openings in this WAA, and the presence of significant prairie communities off ownership, the overall vegetation risk for this area is high.

There are 5.52 miles of road/per mi^2 in PL's portion of the Yager WAA. This is the highest road density of any WAA. Over 50 percent of the roads within the Yager WAA are gravel, and 41 percent of the roads within the WAA are unimproved. The WAA also has the greatest road mileage located directly adjacent to streams. The lower one mile of Yager Creek is in close proximity to a mainline paved road. Portions of the mainstem Yager are also immediately adjacent to gravel roads. Several tributaries to Yager Creek including Cooper Mill and Strawberry creeks, and the upper Yager drainage are in close proximity to mainline and secondary gravel roads. Lawrence Creek, the major tributary to Yager Creek, flows parallel to

Side 8 Road (a mainline gravel road) running immediately adjacent to the lower portion of the stream. Above Side 8 Road are other gravel roads that are in close proximity to Lawrence Creek. Several of the tributaries to Lawrence Creek are also in close proximity to roads including Shaw Creek, the upper portions of Corner and Fish creeks, and Bell Creek. Given high road density and the abundance of streamside roads, the road related risk for the WAA is high.

Van Duzen WAA

Slope classes within the Van Duzen WAA are generally in the 16 to 30 percent and the 31 to 40 percent class. Less than 5 percent of the WAA contains slopes in excess of 70 percent. These low values indicate that the slope risk factor for the WAA is low.

The Larabee soil series dominates the Van Duzen WAA. The dominance of Larabee soils suggests that soils within this WAA are relatively stable. The majority of the WAA (74%) also has a low soil erosion hazard rating. Considering both soil type and the state’s erosion hazard rating, this WAA has a low risk for soils.

The Van Duzen WAA within PL's ownership is dominated by mid-successional stage forest (34%). Areas of mid-successional growth are located throughout the region with the largest concentration in the lower portion of the Van Duzen WAA. Areas with young forests are located in the upper portion of the WAA and in the upper reaches of some tributary streams. Approximately 32 percent of the WAA is composed of young forest or forest openings. The overall vegetation risk for this WAA is therefore moderate.

The portion of the Van Duzen WAA on PL's ownership contains 4.46 road miles/mi^2. This is the second highest road density observed. Nearly three-quarters of the roads within the Van Duzen WAA are unimproved. Some larger tributary streams are next to mainline and secondary gravel roads including Cummings and Grizzly creeks and the upper portion of the Van Duzen River. There are also dirt roads branching off of the mainline roads that are in either close proximity to or immediately adjacent to some smaller tributary streams. Accordingly, the road related risk for this WAA is moderate-high.

Eel WAA

Slope classes within the Eel WAA are primarily in the 51 to 70 percent class, although there are some areas in the 16 to 30 and 31 to 40 percent classes. Approximately 7 percent of the WAA contains slopes in excess of 70 percent. Given the large proportion of the WAA with moderate and high slope categories, the overall slope risk factor for the WAA is high.

The Larabee soil series dominates the Eel WAA. The dominance of Larabee soils suggests that soil within this WAA is relatively stable. The majority of the WAA (70%) also has a low soil erosion hazard rating. However, when compared with the other WAAs, the Eel WAA has the highest percentage (1.69%) of area with a hazard rating in the extreme category. The extreme rating is likely the results of steep slopes as well as vegetation types in upper slope areas. Considering both soil type and the state’s erosion hazard rating, this WAA has a moderate risk for soils.

The Eel WAA within PL's ownership is dominated by late seral forest (37%). The majority of late seral stage vegetation borders the mainstem Eel River. Some mid-successional stage vegetation is located in the middle and upper portions of tributary streams. Only 26 percent of the WAA is composed of young forest or forest openings. The overall vegetation risk for this WAA is therefore low.

The portion of PL's ownership within the Eel WAA contains 4.37 road miles/mi^2. This is a moderate road density compared to the other WAAs. Two-thirds of the roads within the Eel WAA are unimproved. Several mainline and secondary gravel roads run perpendicular to tributary streams and frequently cross stream channels, but gravel roads paralleling streams are generally limited. Mainline dirt roads are in close proximity to Larabee and Newman creeks, but secondary dirt roads generally run perpendicular to stream channels or along ridge lines. The road related risk for this WAA was estimated to be low-moderate.

Bear-Mattole WAA

Slope classes within the Bear-Mattole WAA are generally in the 51 to 70 percent and the 41 to 50 percent class. In addition, approximately 15 percent of the total WAA contains areas with slopes greater than 70 percent. This is the largest proportion of high category slopes observed in any of the WAAs. The overall slope risk factor is therefore considered high.

The Bear Mattole WAA contains primarily Hugo soils. Despite the stable nature of the soils within the WAA, 44 percent of the area has a moderate soil erosion hazard rating. In addition, the Bear-Mattole WAA has the highest percentage (3.51%) of area in the high hazard rating category. The moderate and high ratings relate to the presence of steep slopes in many areas. Considering both soil type and the state’s erosion hazard rating, this WAA has a moderate risk for soils.

The Bear-Mattole WAA within PL's ownership is dominated by hardwood forest (36%). The central and southern portions of the WAA contain the highest concentration of hardwood vegetation on the ownership. Some areas of late seral stage vegetation are also found throughout the WAA, particularly within the western portion. Only 13 percent of the WAA is composed of young forest or forest openings. However, an additional 14 percent of PL’s lands within the WAA are composed of prairies, and prairie communities are common in off ownership portions of the WAA. The overall vegetation risk for this WAA is therefore moderate.

Road density in this WAA is 2.86 miles/mi^2. This is less than half the road density seen in the most heavily roaded WAA. Unimproved roads comprise 97 percent of the road area within the WAA. There are few roads in the Bear-Mattole WAA that are in close proximity or adjacent to stream channels. Instead, the majority of roads are constructed along ridge lines, although they occasionally cross headwater streams or stream channels. This distance from streams ensures limited sediment transport to water bodies despite the high proportion of roads that are unimproved. Overall, the road related risk for this WAA is low.

1.4.5. Summary of Management Concerns and Recommendations

Results for habitat conditions, fisheries, and risk factors can be considered collectively to identify the major management concerns for each WAA. Although not meant to replace site specific data or mitigations, these WAA level concerns were used to identify management actions and monitoring studies that are recommended to ensure that aquatic resources on the ownership are protected. The management area concerns, and recommendations for each WAA are as follows:

Humboldt Bay WAA

With generally low risk factors, fair-good habitat conditions, and healthy fisheries, Humboldt WAA does not appear to be experiencing significant cumulative effects from PL's management activities. However, both the public and agency staff have expressed concern that sediment levels in this WAA have increased and that PL's plans to continue harvesting in this area greatly increase the likelihood that cumulative effects of management will become evident. To address these concerns, PL has proposed that the Freshwater Creek and Elk River basins be the first portion of its lands subjected to watershed analysis (Freshwater study is to begin this summer). In addition, PL is proposing to maintain an extensive monitoring program in the WAA, including new variables expressly designed to determine the impacts of management on sediment production (see Volume IV Part D). The PL's ongoing road storm proofing program in the WAA, and its support of fisheries restoration activities by the Humboldt Fish Action Council, and others, should reduce the potential for cumulative effects to develop in the future.

Road construction practices may need to exceed existing standards within the Humboldt WAA. The presence of unstable and highly erodible soils within this WAA, site surveys, and communication with other fisheries personnel that work in this WAA all indicate a potential for fine sediment problems to develop as management activity increases. In addition, even at current low management levels, fine sediment levels <.85 mm and D_{50} values were worse than in most other WAAs. Monitoring of fine sediment levels in this WAA should therefore be undertaken on a long-term basis. Similarly, given the potential for fine sediment problems, PL should implement stringent construction and maintenance standards for new roads in this WAA. Finally, PL should continue to support the long-term monitoring of salmon and steelhead in this WAA. These long-term studies, when combined with existing fish population data for the WAA, will provide a year to year index of salmonid survival and abundance for the North Coast region.

Yager WAA

The Yager WAA is currently the most heavily impacted portion of PL's ownership with respect to road density, road placement, and the percentage of the area composed of young or open forest. These risk factors, plus past evidence of channel impacts, indicate a risk of management related cumulative effects in the Yager WAA. Given this risk, PL is proposing to conduct cumulative effects assessments in this WAA (see Volume IV Part D). Despite the risk of cumulative effects, the majority of the habitat conditions, and much of the fisheries data, for this WAA demonstrate conditions that are similar to, and in some cases better than, conditions in other study areas. This includes comparisons to unmanaged and lightly managed systems. Thus, although management activities have had many localized impacts on streams within the Yager

WAA, overall conditions in this area do not indicate the presence of widespread degredation. However, the many risk factors, localized impacts, and PL's continued management activities in this WAA increase the importance of continued, and expanded, monitoring efforts.

Monitoring of sediment levels in this WAA needs to be continued to document that instream sediment levels remain at current levels or decrease. This monitoring should include sensitive measures of sediment loading to streams such as maximum pool depth, residual pool volume, transect profile measurements, and thalweg mapping. Similarly, PL's ongoing program of road storm proofing in this WAA is recommended because the high road density, and presence of streamside roads along major watercourses make it likely that significant quantities of road related sediment are being transported into water bodies in this WAA.

The high temperature levels, low canopy, and low instream cover levels in the Yager WAA also indicate a need to evaluate management actions within Watercourse and Lake Protection Zones (WLPZs). Additional studies of water temperature, canopy closure as a function of watershed area, and the location and abundance of LWD and other instream cover are needed to assess the impact of management activities on these variables. Absent this information, restrictive management approaches with WLPZs in the WAA appear warranted, especially along the larger portions of Yager and Lawrence creeks. In addition, because fish are likely to seek refuge in deep pools or cooler tributary streams during periods of high temperature in the mainstem of Yager Creek, a program to identify and protect such thermal refugia should be undertaken.

Van Duzen WAA

High road density, and the large number of road miles along streams make this WAA vulnerable to road related sediment inputs. Habitat and fisheries data indicate that the WAA has conditions intermediate to, and therefore generally similar to, those in other study areas. However, the lack of temperature data and the limited number of stream habitat and fisheries surveys suggest that this result should be viewed cautiously. Overall, the WAA appears vulnerable to site specific problems from roads, but data indicating the presence of cumulative impacts from management were not evident.

Road storm proofing, as used by PL in the Yager and Humboldt WAAs, should be considered for the Van Duzen WAA, particularly for streamside roads along fish bearing streams (e.g., Grizzly Creek, Root Creek). Alternately, more detailed road analyses could be used to identify whether sediment from roads is being transported to streams within the WAA. As noted above, data on habitat conditions and fish abundance in the WAA are not complete. Consequently, it is clear that additional information on habitat and fish abundance needs to be collected, either by PL or the state.

Eel WAA

The Eel WAA contains extensive areas with steep slopes. Some of these steep slopes have produced very large mass wasting events that have severely impacted stream habitats (S. Downie, CDF&G, pers. comm.). A recent report on Bear Creek (PWA 1998b) indicates that the rate of large failures in this watershed is similar to levels under unmanaged conditions, but that management has increased the incidence of small landslides and overall sediment loading rates. This study, and the results here showing slope related risk, habitat indicators of excessive sediment (e.g., high embeddedness, low mean/maximum pool depth) and the presence of streams with little anadromous fish use, all suggest that the Eel WAA is vulnerable to increases in sediment flux rates associated with management activities.

As noted, sediment loading rates already appear to be impacting fisheries habitat. Accordingly, PL should continue to conduct sediment studies to identify the extent to which these sediment impacts are related to its management activities. In keeping with this recommendation, the company has just contracted for a sediment study of Jordan and Stitz creeks. Additional, quantitative studies of channel morphology, as recommended for the Yager WAA, could also be undertaken to document trends in sediment loading in streams. These efforts would identify sediment sources, determine whether impacts to streams are increasing or decreasing, and could be used to determine the types of management approaches that should be used within the WAA in the future. Data to document the role of management in sediment loading is especially important so that PL can prevent being held responsible for impacts that are mostly natural in origin.

Additional sampling of juvenile populations in this WAA should also be conducted in previously unsampled streams, in areas with documented high water temperatures, or in areas with high sediment levels. This sampling would document the extent to which fish populations are doing well in the Eel WAA, despite any potential problems with sediment and temperature.

Bear-Mattole WAA

With the exception of risk factors, data from this WAA are too limited to permit anything except preliminary conclusions about management impacts. The abundance of steep slopes indicate that management activities, particularly road construction and tractor yarding, could result in significant risk of mass wasting or surface erosion in portions of the WAA. However, the abundance of ridgetop roads and low road density make this WAA less susceptible to road-related sediment inputs than most other portions of PL's ownership.

As with the Van Duzen, the primary need for this WAA is to collect additional information on habitat and fish abundance. Without more information, landscape level studies of conditions in the Bear-Mattole WAA will remain preliminary in nature.

Regardless of whether current conditions are a result of management, natural processes, risk factors, or some combination of these elements, habitat and water quality conditions are important because they can limit fish production. Accordingly, the MSHCP, if it is to be effective, needs to contain measures that will minimize and mitigate to the maximum extent practicable the taking of listed species. This requires the analysis of current conditions, as discussed above, as well as a detailed understanding of the life history requirements of the fish species of interest. These life history reviews, which are provided below, can be used to determine the habitat needs of fish on the ownership. Once these needs are identified, MSHCP measures can be designed that will ensure the protection and restoration of these elements of the stream ecosystems on PL's ownership.

REFERENCES

Armour, C.L. 1991. Guidance for evaluating and recommending temperature regimes to protect fish. United States Fish and Wildlife Service Biological Report 90(22).

Baltz, D.M., B. Vondracek, L.R. Brown, and P.B. Moyle. 1991. Seasonal changes in microhabitat selection by rainbow trout in a small stream. Transactions of the American Fisheries Society 120:166-176.

Bilby, R.E., and J.W. Ward. 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. Transaction of the American Fisheries Society 118:368-378.

Bilby, R.E., and P.A. Bisson. 1992. Allochthonous versus autochthonous organic matter contributions to the trophic support of fish populations in clear-cut and old-growth forested streams. Can. J. Fish. Aquat. Sci. 49:540-551.

Bisson, P.A., J.L. Nielsen, R.A. Palmason, L.E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Pages 62-73 in N.B. Armantrout, editor. Acquisition and utilization of aquatic habitat information. American Fisheries Society, Bethesda, Maryland.

Bjornn, T.C., M.A. Brusven, M.P. Molnau, J.H. Milligan, R.A. Klamt, E. Chacho, and C. Schaye. 1977. Transport of granitic sediment in streams and its effects on insects and fish. College of Forestry, Wildlife and Range Sciences. September 1977. Bulletin Number 17.

Brumback, D., and J. Ellinwood. 1988. Freshwater Creek Salmon Escapement Estimate.

Brusven, M.A., W.R. Meehan, and J.F. Ward. 1986. Summer use of simulated undercut banks by juvenile chinook salmon in an artificial Idaho channel. North American Journal of Fisheries Management 6:32-37.

Busby, P.J., T.C. Wainwright, G.J. Bryant, L.J. Lierheimer, R.S. Waples, F.W. Waknitz, and I.V. Lagomarsino. 1996. Status review of west coast steelhead from Washington, Oregon, and California. National Oceanic and Atmospheric Administration (NOAA) Technical Memorandum NMFS-NWFSC-27, Seattle, Washington.

Carlson, J.Y., C.W. Andrus, and H.A. Froehlich. 1980. Woody debris, channel features, and macroinvertebrates of streams with logged and undisturbed riparian timber in northeastern Oregon, USA. Canadian Journal of Fisheries and Aquatic Sciences 47:1103-1111.

Cederholm, C.J., L.M. Reid, B.G. Edie, and E.O. Salo. 1981. Effects of forest road erosion on salmonid spawning gravel composition and populations of the Clearwater River, Washington. Fisheries Research Institute, University of Washington, Seattle, Washington.

Chapman, D.W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society 117:1-21.

Chapman, D.W. and K. Knudsen. 1980. Channelization and livestock impacts on salmonid habitat and biomass in western Washington. Transactions of the American Fisheries Society 109:357-363.

Flosi, G., and F.L. Reynolds. 1994. California salmonid stream habitat restoration manual. Second Edition.

Heifetz, J., M.L. Murphy, and K.U. Koski. 1986. Effects of logging on winter habitat of juvenile salmonids in Alaskan streams. North American Journal of Fisheries Management 6:52-58.

Holtby, L.B. 1988. The effects of logging on the coho salmon of Carnation Creek, British Columbia. Pages 159-174 in T.W. Chamberlin, editor. Proceedings of the Workshop: Applying 15 years of Carnation Creek Results.

House, R.S., and P.L. Boehne. 1986. Effects of instream structures on salmonid habitat and populations in Tobe Creek, Oregon. North American Journal of Fisheries Management 6:38-46.

Humboldt Fish Action Council (HFAC). 1995. Five year plan: 1994/95 - 1999/2000. Humboldt Fish Action Council, Arcata, California.

Knopp, C. 1993. Testing indices of cold water fish habitat. Final report for North Coast Regional Water Quality Control Board in cooperation with the California Department of Forestry.

Lisle, T.E. 1981. The recovery of stream channels in North Coastal California from recent large floods. in Habitat Disturbance and Recovery. Proceedings of a Symposium, January 29, 1981.

Lisle, T.E. 1986. Effects of woody debris on anadromous salmonid habitat, Prince of Wales Island, southeast Alaska. North American Journal of Fisheries Management 6:538-550.

McMahon, T.E. 1983. Habitat suitability index models: Coho salmon. FWS/OBS-82/10.49. U.S. Fish and Wildlife Service.

McMahon, T.E., and G.F. Hartman. 1989. Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 46:1551-1557.

McNeil, W.J., and W.H. Ahnell. 1964. Success of pink salmon spawning relative to size of spawning bed materials. United States Fish and Wildlife Service Special Scientific Report. Fisheries 469.

Murphy, M.L., and J.D. Hall. 1981. Varied effects of clear-cut logging on predators and their habitat in small streams of the Cascade Mountains. Oregon Can. J. Fish. Aquat. Sci. 38:137-145.

Murphy, M.L., J. Heifetz, S.W. Johnson, K.V. Koski, and J.F. Thedinga. 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan streams. Canadian Journal of Fisheries and Aquatic Sciences 43:1521-1533.

NCRWQCB (See Knopp 1993)

Nickelson, T.E., J.D. Rodgers, S.L. Johnson, and M.F. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Can. J. Fish. Aquat. Sci. 49:783-789.

Pacific Watershed Associates. 1998a. Sediment source investigation for the lower Eel River, prepared for the United States Environmental Protection Agency, Humboldt County, CA.

Pacific Watershed Associates. 1998b. Sediment source investigation and sediment reduction plan for the Bear Creek Watershed, Humboldt County, California, prepared for the Pacific Lumber Company, Scotia, CA.

Peterson, N.P., A. Hendry, and T.P. Quinn. 1992. Assessment of cumulative effects on salmonid habitat: some suggested parameters and target conditions. Timber, Fish, and Wildlife TFW-F3-92-001. Washington Department of Natural Resource, Olympia, Washington.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. USFWS. General Technical Report INT-138.

Plum Creek Timber Company. 1996. Draft multi-species Habitat Conservation Plan. Central Cascades Mountain Range, Washington.

Powell, L.H. 1987. Stream channel morphology changes since logging. Pages 16-25 in T.W. Chamberlin, editor. Proceedings of the Workshop: Applying 15 years of Carnation Creek Results.

R2 Resource Consultants, Inc. 1996a. Analysis of Pacific Lumber Company's watershed analysis areas. Prepared for: The Pacific Lumber Company. Seattle, Washington.

R2 Resource Consultants, Inc. 1996b. Literature summary of riparian management zones. Prepared for: The Pacific Lumber Company. Seattle, Washington.

R2 Resource Consultants, Inc. 1997. Literature summary of large woody debris. Prepared for: The Pacific Lumber Company. Seattle, Washington.

Reiser, D.W., and R.G. White. 1988. Effects of two sediment size-classes on survival of steelhead and chinook salmon eggs. North American Journal of Fisheries Management 8:432-437.

Rosgen, D.L. 1994. A classification of natural rivers. Catena 22: 169-199, Elsiver Science, B.V. Amsterdam.

Shepard, B.B., S.A. Leathe, T.M. Weaver, and M.D. Enk. 1984. Monitoring levels of fine sediment within tributaries to Flathead Lake, and impacts of fine sediment on bull trout recruitment. Pages 146-156 in F. Richardson and R.H. Hamre, editors. Wild trout III. Federation of Fly Fishers and Trout Unlimited, Vienna, Virginia.

Shirvell, C.S. 1990. Role of instream rootwads as juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*) cover habitat under varying streamflows. Can. J. Fish. Aquat. Sci. 47:852-861.

Steele and Stacey. 1994. Coho salmon habitat impacts. Qualitative assessment technique for registered professional foresters. California Department of Fish & Game. November 1994. Draft No.2.

Thedinga, J.F., M.L. Murphy, J. Heifetz, K.V. Koski, and S.W. Johnson. 1989. Effects of logging on size and age composition of juvenile coho salmon (*Oncorhynchus kisutch*) and density of presmolts in southeast Alaska streams. Can. J. Fish. Aquat. Sci. 46:1383-1391.

Tschaplinski, P.J. 1987. The use of estuaries as rearing habitat by juvenile coho salmon. Biological consultant, 1146 Union Road, Victoria, British Columbia V8L 2S1. pp 123-142.

Tschaplinski, P.J., and G.F. Hartman. 1983. Winter distribution of juvenile coho salmon (*Oncorhynchus kisutch*) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. Canadian Journal of Fisheries and Aquatic Sciences 40:452-461.

Washington State Department of Natural Resources (WADNR). 1994. Standard methodology for conducting watershed analysis. Washington Department of Natural Resources, Olympia, Washington.

Weaver, W.E., D.K. Hagans. 1994. Handbook for forest and ranch roads. A guide for planning, designing, constructing, reconstructing, maintaining, and closing wildland roads. The Mendocino County Resource Conservation District, California.

Weyerhaeuser Company. 1996. Multispecies Habitat Conservation Plan for the Willamette Timberlands. Prepared by: Hampton Communications, Puyallup, Washington.

Winzler & Kelly. 1980. The Pacific Lumber Company. Yager Creek Fish Habitat Investigation Humboldt County, California.

Young, M.K., W.A. Hubert, and T.A. Wesche. 1991. Selection of measures of substrate composition to estimate survival to emergence of salmonids and to detect changes in stream substrates. North American Journal of Fisheries Management 11:339-346.

cases because of high variability in the values observed within the groups being compared. Average values for each stream habitat variable in each WAA are presented in Table 2 along with the numeric criteria used to define good and poor conditions. Review of this table indicates that both favorable and poor habitat conditions were present within each study area. For example, the Humboldt WAA had the best observed values for percent canopy, percent pools, and percent fines <4.7 mm, but the worst observed values for pool volume and depth.

Analysis of habitat and fisheries data for each WAA was conducted as described in Sections 1.2.1. and 1.2.2. General results for each WAA can be summarized as follows:

Humboldt Bay WAA

This WAA had the poorest observed values for all three variables examining pool volume/depth, high percent fines <0.85 mm, low gravel dominance, and the smallest average substrate size (i.e., D_{50}). However, Humboldt WAA also had the best values for percent fines <4.7 mm, percent canopy, and percent pools, and good values for LWD and water temperature. Poor sediment values may be due to the presence of unstable Atwell soils in the WAA. Similarly, low values for pool depth and volume were due, in part, to the many small tributaries that were surveyed; these tributaries had correspondingly small pools. More positively, temperature conditions within the Humboldt Bay WAA are consistently within the range preferred by salmonids. Furthermore, mean percent canopy in this WAA is the highest measured (>80%). Low water temperatures and a high percent canopy present favorable conditions for fish. Pool abundance was also the highest observed. Thus, although pools in the WAA are small, they appear to be abundant.

Overall, this WAA has sediment problems that would limit spawning and invertebrate production, and a limited number of deep pools for rearing, but is well shaded and has cool temperatures. Long term population records for fish have documented good fish production in this WAA, but suggest that the carrying capacity of the system is limited by the amount of rearing habitat.

Yager WAA

Percent canopy in this WAA was the second lowest observed. However, values for mean and maximum pool depth, residual pool volume, embeddedness, percent fines <0.85 mm, percent cover, gravel dominance, LWD, and average substrate size were better than for any other WAA. Low fine sediment levels indicate that spawning success for trout and salmon should be higher than in other areas. In addition, the Yager WAA contains a fair number of very large pools relative to pools in other areas. This should benefit both upstream migration of spawning adults and rearing of juvenile fish. It is not clear whether pool depths in this WAA are good because of the generally larger streams that are present, or because sediment infilling is limited, or both.